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THE MACHINE STRESS RATED LUMBER MARKET

by

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B.A. Montana State University, 1962

Presented in partial fulfillment of the requirements for the degree of

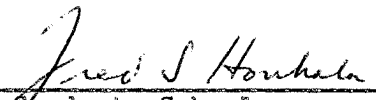
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1965

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Chairman, Board of Examiners


Dean, Graduate School

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ACKNOWLEDGMENTS

The decision to write an analysis of the machine stress rated lumber market originated from personal interest in two separate fields of study. One was the role of marketing in today's American economy and the other was the forest products industry. The machine stress rated lumber market combines aspects of the two fields. Moreover, it offers opportunity to study a marketing structure that lies on the threshold of accepting a technically modern innovation. This paper seeks to present an understanding of this development from the marketing manager's viewpoint.

Appreciation must be extended to spokesmen of the private lumber companies contacted for their time and practical insight. Lumber associations, journals and research organizations, and government laboratories, committees and agencies have also been helpful in presenting results of their studies. I am obliged to members of the faculty and staff of Montana State University for providing background guiding me into this area of study. Particular influence must be accredited members of the thesis committee, Norman E. Taylor, Lawrence J. Hunt, and John P. Krier.

I accept responsibility for all errors herein.

W.F.J.

THE MACHINE STRESS RATED LUMBER MARKET:

An Abstract

Buyers of building materials require that the materials they purchase meet certain specifications according to the uses intended for the materials. Unlike most other building materials lumber cannot be engineered to desired strength specifications. Until the development of stress rating machines, there had been no practical way to non-destructively test the strength of structural lumber. Instead, samples from groups of lumber were destructively tested and the rest of the lumber was graded according to the weak specimens. Because of the wide variance between strength and appearance, most pieces were far stronger than the grade implied. Machine stress rating of lumber provides a more accurate method of evaluating lumber strength and hence should have desirable effects on the demand for and marketing of lumber.

A survey of the nature of the market for lumber and the experiences of two Rocky Mountain region firms who have installed stress rating machines is undertaken to analyze and compare the extent and characteristics of the expected market with the actual experiences of firms using the new machines. Included in the analysis is a discussion of some of the pertinent problems of the lumber market and how the development of stress rating machines may alter the marketing activities of lumber processors.

TABLE OF CONTENTS

CHAPTER		PAGE
	ACKNOWLEDGMENTS	ii
	TABLE OF CONTENTS	iii
I.	INTRODUCTION	1
	Improving the Structural Lumber Market	
	Lack of Marketing Information	
	Limitations of the Study	
II.	THE STRUCTURAL LUMBER MARKET	5
	Production and Consumption	
	Demand for Structural Lumber	
	Supply of Structural Lumber	
	Competition in Residential Construction	
	Merchandising of Structural Lumber	
III.	THE DEVELOPMENT OF MACHINE STRESS RATING	21
	Research in the Lumber Industry	
	Non-destructive Testing of Wood	
	Machine Stress Rating	
	Mechanical Problems in Machine Stress Rating	
	Technology Affecting Machine Stress Rating	
IV.	THE MARKETING OF MACHINE STRESS RATED LUMBER	33
	Acceptance by Industry and Government	
	Industrial Application	
	Demand from the Market	
	Machine Stress Rating in a Dynamic Market	
	Case Studies on Machine Stress Rating	
V.	CONCLUSION	59
	Outlook for Machine Stress Rated Lumber	
	Decision Criteria in Marketing Machine Stress Rated Lumber	
	APPENDICES	65
	Appendix A. Mechanical Stress Rating	
	Appendix B. CLT-1	
	Appendix C. Stress-O-Matic	
	BIBLIOGRAPHY	76

CHAPTER I

INTRODUCTION

Improving the Structural Lumber Market

The American economy is largely consumer oriented. No longer is the consumer dependent upon any one product. He has available an increasing range of products from which to choose. Consequently, the producer must cater to the consumer's tastes as never before.

The producer can make a product appeal to consumers in different ways. He can alter it in shape, color, design, size, composition, or utility. In addition, alternatives are available in the product's merchandising, distribution, pricing, and packaging. Consumer services, such as advertising which promotes attractive images and associations of the product to the consumer, can also be used. It is the responsibility of the marketing manager to understand how to organize these elements into a sound product mix and then to evaluate alternative courses of action.

Structural lumber suitable in size for machine stress rating is used predominantly as light framing material in residential construction. The major appeal to buyers is its strength, which is determined from such factors as shape, size, and composition of the material. Therefore, marketing research emphasis should seek means of maximizing the value of this strength to the buyer.

Structural lumber competes with steel, aluminum, cement, brick, block, and glass homebuilding materials. All these competing materials

may be engineered to desired strength specifications, but lumber cannot. Until the development of the stress rating machine, there had been no practical way for a sawmill to non-destructively test the strength of structural lumber. It was necessary to destructively test a sample of visually similar specimens and then grade the group according to the strength of the weaker pieces tested. Because of the wide variance between strength and appearance, most pieces were far stronger than the grade implied. Because they were visually similar to weaker pieces, the value of their strength had to be downgraded. The stress rating machine does not base its rating on human evaluation of visual characteristics, but on a test of the elasticity, or bending strength, of each piece individually. This method, shown to be more accurate than the former within limits of a few recognized exceptions, makes possible the assignment of higher stress values to most visually graded lumber. By improving the value of strength of structural lumber to the buyer, producers of machine stress rated lumber improve consumer demand.

Lack of Marketing Information

Because the application of machine stress rating is so new, relatively little has been published on the subject. Current articles on it generally are concerned only with the technical aspects of its operation or its relationship to the production process. Notably absent in current trade literature is an analysis of the machine's potential impact upon the marketing of structural lumber. Yet it is this aspect that should ultimately justify the capital outlay for its purchase, installation, and operation.

Analysis of the marketing of machine stress rated lumber may provide several important benefits. Most important, it should provide a background of general knowledge useful in deciding what method to employ in the stress rating of lumber. An outlay of up to \$45,000 should justify more investigation than merely a review of a machine's potential in production processes. This study seeks to emphasize the advantages of a consumer oriented perspective in decision making. The author believes that businessmen too often base investment decisions on cost and technical considerations, without proper evaluation of the market impact and overall profit consequences.

Machine stress rating is new. Before full acceptance by the housing industry, as well as the lumber industry, the machine's competence and significance need to be appreciated. Hence, this analysis can serve, also, as a reference acquainting those involved in the production, marketing, and consuming process of structural lumber with the machine's status.

Limitations of the Study

A study of this general scope cannot make decisions for a firm. Each firm lies in a unique environment and is subject to a set of conditions with which a general treatise cannot be specific. Furthermore, this analysis is not concerned with relating the overall field of marketing to machine stress rating, but rather only those topics directly involved in the marketing of structural lumber which provide basic perspective to this development. Thus many topics, such as market programming or selection of channels of distribution, are omitted.

Machine stress rating thus far has been commercially applied only to structural lumber nominally two inches in thickness. This material is thicker than board lumber but less thick than timbers, and is classified under the general heading of "dimension lumber." Structural lumber of board or timber size, unable to be received by present stress rating machines, has been considered not applicable to the study.

Data have come primarily from current trade publications and from personal correspondence. Since major progress in machine stress rating has developed only recently, the statements have at times been contradictory, and some areas have been only partially discussed.

Throughout the study, data cited shifts between lumber, soft-wood lumber, framing lumber, structural lumber, and dimension. This has been necessary due to limited sources of data and methods of collection. It has been advantageous to include this material to present at least some understanding of particular phases of the machine stress rated lumber market. The reader must keep in mind, however, that some of these classifications may include more than lumber of a size suitable for machine stress rating.

CHAPTER II

THE STRUCTURAL LUMBER MARKET

The lumber industry is faced with mounting problems. John A. Zivnuska, a prominent forest economist, wrote in the fall of 1963 that, "This year lumber is probably the most seriously troubled major manufacturing industry in our expanding economy."¹ In that same year Random Lengths reported, "The U. S. lumber industry, and the forest products industry in general, is having a bad time. It is beset on one side by sharp internal conflict and competition, and by overcapacity for the size of its markets. The domestic industry is in conflict with national policy on both lumber imports and log exports. It is being beleaguered from the outside by the competition of new building products."² Since the writing of these reports, the condition of the lumber industry has begun to improve. Nonetheless, these reports illustrate the generally unfavorable trends of the lumber industry relative to the American economy.

Production and Consumption

Structural lumber is cut mainly from softwoods. Douglas fir is one of the strongest species of softwoods. Its load bearing capacity equals that of many mild steels, and yet it

¹John A. Zivnuska, "The Future of Wood in a Competitive Market," Forest Industries, XC (October, 1963), p. 41.

²William Dean (ed.), Random Lengths (April 26, 1963), p. 1.

is much lighter.¹ Western larch has strength characteristics similar to Douglas fir which allow the two species to be intermingled and marketed as a common product. Douglas fir, larch, and western hemlock provide better than one-third of the American commercial softwood lumber supply. In recent years southern yellow pines have provided about one-fourth of the country's production of softwood lumber. Southern pines are competing in the eastern markets directly with northwestern Douglas fir, over which they have distinct rail-freight cost-advantages in much of the South and East.² Other softwoods are the spruces, cedars, cypresses, redwood, true firs, and other pines.

Softwood lumber is divided into three main product classes: structural lumber, yard lumber, and factory and shop lumber. Structural lumber is usually stress graded in larger size pieces and used where strength is the most important criterion. It differs from yard lumber in that the latter is intended for general construction purposes, where strength is not the primary consideration; its grade being determined mainly from the appearance of the best face. It is claimed that 80 to 85 per cent of softwood lumber is manufactured into yard lumber.³ Factory and shop lumber, the third class, is lumber

¹"1965 Western Lumber Technical Manual" (Portland: Western Wood Products Association, 1965), p. 6.

²W. Halder Fisher, "Report to the National Bureau of Standards, United States Department of Commerce, on the Economic Impact that can be expected to Follow the Adoption of 'A Proposed Revision of SPR 16-53 ALS for Softwood Lumber'" (Washington, D. C.: Battelle Memorial Institute, July 6, 1964), pp. 8-10.

³Nelson C. Brown and James S. Bethel, Lumber (2d ed.: New York: John Wiley & Sons, Inc., 1958), p. 248.

normally cut up for remanufacturing before ultimate use.¹

About 30 per cent of all lumber used in the United States in 1952 went into residential construction (the housing industry).² Today, about 75 per cent of the lumber used in the United States goes into residential construction.³ The consumption of lumber per dwelling unit by type of lumber in 1953 was as follows:

CONSUMPTION OF LUMBER PER DWELLING UNIT

BY TYPE OF LUMBER IN 1953⁴

Framing Lumber	70.5%
Wood Sheathing	21.0
Wood Siding	3.0
Hardwood	<u>5.5</u>
Total	100.0%

In nonresidential construction, a substantial lumber market, lumber is used predominantly in a facilitating role in items such as commercial and industrial buildings, public utilities, highways, military installations, sewer and water facilities, and structures for conservation and development of natural resources.⁵ A 1953 survey of a

¹Ibid., pp. 246-48.

²"Future Demand for Timber" (Reprinted from Timber Resources for America's Future, Forest Resource Report No. 14, Separate No. 9; Washington, D. C.: U. S. Forest Service, January, 1958), p. 375.

³Letter from E. M. Williston, Technical Director, Softwood Lumber, Weyerhaeuser Company, October 23, 1964, p. 2.

⁴"America's Demand for Wood 1929-1975" (Summary of a report by Stanford Research Institute to Weyerhaeuser Timber Company; Tacoma: Weyerhaeuser Timber Company, 1954), p. 40.

⁵"Future Demand for Timber," p. 384.

thousand large nonresidential contractors found lumber's use to be divided as follows:

LUMBER USED IN NONRESIDENTIAL CONSTRUCTION IN 1953¹

Concrete Forms	58%
Framing and Trim	20
Scaffolding	10
Bracing, Shoring, Decking	9
Temporary Buildings, Skids, Other	<u>3</u>
Total	100%

Concrete forms are built chiefly with board lumber or plywood, with dimension stiffeners. In this and the other use categories indicated it can be seen that the two-inch structural lumber applicable to the stress rating machines is not a major material in nonresidential construction. Residential construction is the predominant market for machine stress rated lumber.

Demand for Structural Lumber

Although end uses of structural lumber can be fairly well determined, locating and measuring demand is rather difficult. This fact is more understandable when one considers the nature of the construction industry. Important roles are played by architects, engineers, financial agencies, and local building code authorities in establishing or perpetuating particular construction practices. Furthermore, the cost of all lumber (much less that of structural lumber) is but a small part of the total cost of a house to a consumer. Consequently,

¹"America's Demand for Wood," p. 42.

a study of the desires of homebuyers or other users of structures does not provide a realistic basis for measuring future demand for structural lumber.¹

Price trends do not offer a reliable guide for anticipating future demand due to unusual influences upon the economy. John A. Zivnuska's study² of the lumber price trend from 1919 to 1953 illustrates this fact. Erratic fluctuations between 1919 and 1921 followed World War I. From 1929 to 1942, the Depression was placing its scars upon the economy. Next came World War II's impact with attendant materials restrictions, and then a period releasing the consumer's pent-up demand. Equally distorting to the price trend are changes occurring in the supply function, a subject that will be taken up later. Of significance is the fact that the price of lumber in constant dollars³ more than doubled in the 34 years following 1919. This acknowledges an imbalance between demand and supply.

In a study⁴ conducted for the U. S. Forest Service during the 1950's, Professor I. I. Holland of the University of Illinois College of Agriculture advised that in the housing market the price elasticity of the demand for framing lumber was not significantly different from zero. This means that, according to the study, outside factors tend

¹Fisher, p. 22.

²John A. Zivnuska, "Supply, Demand, and the Lumber Market for Domestic Production," Journal of Forestry, LIII (August, 1955), pp. 547-53.

³Ibid., pp. 547-48.

⁴Fisher, pp. 21-62.

to separate the demand for framing lumber from being influenced directly by changes in its price. His basis for this finding stemmed primarily from studies showing that consumers buy housing, not the lumber which goes into construction. While generally true for the short-run, he believed that it did not necessarily apply to the long-run. To the degree that lumber and other building materials become increasingly competitive because of technical innovations, the relevant cross-elasticities of demand would probably rise.

Because the housing industry is structural lumber's biggest market, trends within it are important in determining future demand. Single family homes use more framing pieces per living unit than do multi-family structures. Consequently, producers of structural lumber were alarmed in 1963 at the reports showing a consistent growth in the multi-family segment of new construction. Particularly disquieting were reports in the fall of that year that the next six to eight years rental housing would be an important factor in new construction. So bad did the market seem that one Random Lengths report stated, "The market appears to be working its way along a bottom. . . . Dimension in all species . . . continues to drag . . . in early September there simply was no market."¹

Much blame was placed on rental housing. And yet, the need for high-density housing in the major population centers was undeniable. The nation's six largest population centers accounted for nearly half of all new rental construction.²

¹Dean (September 27, 1963), p. 3.

²Ibid., p. 2.

The future looked no better. Population projections at that time for 1950 to 1970 showed a major increase in the youngest and oldest age brackets, generally demanding smaller and cheaper rental units.¹

POPULATION PROJECTIONS IN MILLIONS TO 1970 BY AGE GROUP²

Age group years	1950	Year 1960	1970	1950-1960	1960-1970
20-29	23.9	22.1	30.8	-2.2	+8.7
30-39	22.9	24.5	22.5	+1.6	-2.0
40-49	19.3	22.6	24.3	+3.3	+1.7
50-64	21.6	25.3	29.9	+3.7	+4.6
65-Over	<u>12.3</u>	<u>16.7</u>	<u>20.0</u>	<u>+4.4</u>	<u>+3.3</u>
All ages	151.3	180.7	214.2	+29.4	+33.5

With this potential age-group demand, other factors existed which could possibly contribute to a boom in rental construction. There was an especially favorable money market in long-term apartment mortgages. The builders had access to more capital and were becoming more sophisticated. Accelerated depreciation rules favored apartment lending. Underbuilding of rental structures had occurred during the post-war boom. Greater prosperity allowed increasing separation of relatives. And the decreasing trend in the post-war inflationary rate increased speculation in real estate holdings.³

More and more the financial risks involved in short-term home

¹Ibid., p. 1.

²Ibid.

³Ibid., pp. 1-2.

ownership by a highly mobile population began to be attacked by spokesmen for the lumber industry. Their major targets were conservative building code and zoning requirements and construction costs due to inefficient distribution and use of materials.¹

The increase in multiple-unit housing continued for several years. An example of this change in activity can be illustrated in the dwelling unit construction in Los Angeles County in 1955 and 1963.

DWELLING UNIT CONSTRUCTION IN LOS ANGELES
COUNTY IN 1955 AND 1963²

	<u>1955</u>	<u>1963</u>
Total Units	82,000	76,000
Types of Units		
Multiple	23%	70%
Duplex	5	4
Single	<u>72</u>	<u>26</u>
Total	100%	100%

New housing units started in the United States per year between 1959 and 1963 were divided as follows:

¹Ibid., p. 2.

²Dean (July 17, 1964), p. 1.

NEW HOUSING UNITS STARTED IN THE UNITED STATES

IN THE YEARS 1959 THROUGH 1963¹

	<u>1959</u>	<u>1960</u>	<u>1961</u>	<u>1962</u>	<u>1963</u>
Total Units Started (in thousands)	1553.1	1296.0	1355.4	1492.4	1617.7
Type of Units					
Multiple	16%	18%	24%	29%	34%
Duplex	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>	<u>4</u>
Single	<u>80</u>	<u>78</u>	<u>72</u>	<u>67</u>	<u>62</u>
Total	100%	100%	100%	100%	100%

Halfway through 1964 a change finally began to take place. Multiple construction began to taper. Mortgage money for apartment construction was tightened. High rates of apartment vacancies became noticeable and more and more new starts were questioned. While single unit housing did not appear to be strengthening, by holding its own the decline in total starts would increase its percentage.²

By the end of October, 1964, an increase in the rate of housing became apparent and, with the corresponding drop in permits for multifamily units, prospects improved in the market for lumber suitable for machine stress rating.³

¹Harry Hansen (ed.), The World Almanac and Book of Facts for 1965; . . . 1964; . . . 1963; . . . 1962, and . . . 1961 (New York: New York World-Telegram and The Sun, 1965, 1964, 1963, 1962, and 1961, respectively).

²Ibid.

³Dean (October 30, 1964), pp. 1 and 10.

Economic projections of the future demand for lumber have been made and were published¹ in 1958 by the U. S. Department of Agriculture. The report first estimated the economy's likely expansion. Second, it indicated lumber's role in the economy. Third, projections for end uses were made. Its basic conclusions were:

I. Expansion of the Economy.

- a. The population upsurge will continue.
- b. Output of all goods and services must greatly increase.
- c. Average man-hour productivity is increasing.
- d. The annual average workweek is shortening.
- e. Per capita disposable income may double by year 2000.
- f. Raw materials input will increase.

II. Lumber's Role in the Economy.

- a. A decreasing percentage of industrial wood is being used for lumber.
- b. Lumber prices are expected to maintain their current relevance in relation to substitute materials.

III. Future Demand for Lumber.

- a. While demand in residential construction will drop from 1950-1955 levels during the next few years, large demand must develop after 1960.
- b. Housing has tended to move out of the field of heavy construction, where concrete and steel have strong competitive advantages, toward the field of light construction.
- c. The average size of dwelling units will probably increase.
- d. The average lumber use per house will continue to decrease.
- e. Other materials apparently will be substituted some in nonresidential construction.
- f. The trend in buildings of many kinds is away from the multiple-story toward the single-story structure, enhancing possibilities for the use of structural lumber.
- g. Future demand for lumber in maintenance should parallel that in residential construction.

¹"Future Demand for Timber," pp. 357-422.

- h. Lumber consumption should be less sensitive to price increases with the passage of time.

These projections were based on assumptions of peace with continued military preparedness, economic prosperity reflected in high-level employment, Bureau of the Census population projections, and the trend in prices of timber products paralleling that of competing non-timber products.

Supply of Structural Lumber

The lumber industry is characterized by a few industrial giants and a host of small firms. Unlike the automotive, steel, and many other of today's industries, the combined production of the small firms exceeds that of all the giants.¹ In 1959, the four largest companies produced about 7.5 per cent of the total output; no other company produced as much as 1 per cent of the total.² Production relationships in 1961 were as follows:

1961 PRODUCTION RELATIONSHIPS³

<u>Number of Mills</u>	<u>Mill Capacity</u>	<u>% of Total Production</u>
65	50 MMbf - plus	18
551	10 MMbf - 50 MMbf	38
32,000	less than 10 MMbf	44

Total lumber production in 1909 was 44,510 MMbf.⁴ In 1958, total

¹Zivnuska, "The Future . . .," p. 41

²Ibid.

³Ibid., p. 101.

⁴"Lumber Industry Facts 1960-1961" (Washington, D. C.: National Lumber Manufacturers Association), p. 22.

lumber production had dropped to 33,385 MMbf,¹ although U. S. population had almost doubled and total economic activity had probably risen about four-fold.² This decline in the lumber market is claimed to be due to supply, as well as demand, according to a thesis³ presented by Zivnuska in 1955. This he derived from the trend from the 1920's to the 1950's in which prices doubled for lumber.

Competition in Residential Construction

Competition between types of building materials plays an important role in marketing of structural lumber. However, it does not appear to lie significantly in the realm of price. Professor I. I. Holland estimates the cross-elasticity of demand for framing lumber (the proportionate change in the quantity purchased as a result of 1 per cent change in the price of a competing product) to be quite low; somewhere in the range between 0.5 and 0.0, and probably in the lower half of that range.⁴ Moreover, like elasticity of demand for framing lumber, in the short run it tends to approach zero.⁵

Major materials industries competing with structural lumber are steel, aluminum, plastics, concrete, fibreglass, and cement.⁶ More specifically, structural lumber competes with steel and aluminum

¹Ibid.

²Zivnuska, "The Future . . .," p. 40.

³Zivnuska, "Supply"

⁴Fisher, p. 21. ⁵Ibid., p. 22.

⁶Zivnuska, "The Future . . .," p. 40.

trusses, beams, and struts. There are new forms of panel construction using plastics, fibreglass, and metals in honeycomb sheets, and/or blocks.¹ Since World War II concrete slab foundations have provided stiff competition in the residential construction market.²

Building code regulations have been established, forming an effective type of competition even within species. For example, coastal Douglas fir historically has been given a key competitive position. Producers of inland Douglas fir hope to improve their competitive position with machine stress rating by showing that the originally set variances between the strength of inland and coastal Douglas fir are often inaccurate and unfair to the former.

While the demand for lumber has remained at about 30 billion board feet a year since the end of World War II, interregional competition has altered the shares of the market supply. There have been increases of production in the Western Pine and Canadian regions with concurrent declines in the Southern Pine and Douglas Fir regions.³

American softwood lumber competes in seeking export markets in other countries but faces stiffer competition in competing against imports, especially those from Canada. Export markets have been largest in Asia, Africa, and Latin America, but these are declining. While the Canadian industry is faced with a disadvantageous condition of undercapacity, imports to the United States are aided by a very

¹Fisher, p. 20.

²Zivnuska, "The Future . . .," p. 41.

³Dean (June 5, 1964), p. 10.

favorable exchange rate between U. S. and Canadian dollars, lower cargo rates on marine shipments, and a generally lower price for grades the same as those of U. S. lumber. Furthermore, there is virtual unexploitation of the characteristically old-growth Canadian forests.¹

Merchandising of Structural Lumber

The marketing of substitutes has in most cases been more efficiently directed in all of its numerous bearings than that of lumber. . . . Organized advertising, in the lumber industry conspicuous mainly by its absence from all channels reaching the ultimate consumer, has, in many competing industries, fully kept pace with general American advertising development and in itself has made possible the utilization of a long list of substitutes. . . ."

So read a report published by the U. S. Department of Agriculture in 1917.² It is generally true today.³ Add to that the numerous changes in the character of modern construction and the American lumber industry is in serious trouble. The structure of the lumber industry is obsolescent. Because of its extensive composition of small firms, the industry finds itself more concerned with the complexities and seriousness of daily problems than with being an effective competitor in technological innovation and aggressive marketing against competing building materials industries.

Some progress is being made. Lumbermen are pursuing new systems

¹Fisher, pp. 36-39.

²Rolf Thelan, "The Substitution of Other Materials for Wood" (United States Department of Agriculture Report No. 117; Washington, D. C.: Government Printing Office, 1917), pp. 473-75.

³Zivnuska, "The Future . . .," p. 40.

of product names and grades aimed at being more intelligible to their customers. Types of products and services which the customer is expected to need within a few years are starting to be more actively studied and developed. Examples of these are the building systems recently developed by the Timber Engineering Company and the Unicom method advanced by the National Lumber Manufacturers Association.

Structural lumber suitable for machine stress rating has a limited area of merchandising because of its simple nature. Its composition is mainly limited to about fifteen species of softwoods, its size is currently limited to nominally 2 inches thick by 4 inches or more in width, and its utilization is limited almost entirely to strength appeal. The values determined and assigned to the strength of structural lumber are not conclusive for the individual pieces. That is why the existing grades and stress ratings are causing such a furor in the marketing of structural lumber. Modern research has shown that the strength of most individual pieces of lumber not only as been underrated and misunderstood, but that this misunderstanding appears to have cost the lumber industry hundreds of millions of dollars.¹ In the words of Professor Dietz of M.I.T., "All small houses are overbuilt. You can't say they are overengineered, because they are hardly engineered at all; they're just overbuilt."² The statistical probability has been established that 95 per cent of the

¹"Round Table on the Engineered Use of Wood Suggests Eleven Ways to Cut the Cost of Better Homes by \$200 Million Plus" (Editorial reprint from House & Home, June, 1963; New York: TIME, Inc., 1963), p. 130.

²Ibid.

pieces in a grade must be at least 25 per cent stronger than they are given credit for.¹ (A safety factor is then superimposed above this.) This excessive requirement, one which structural lumber's competitors do not need nor have, means either an increased cost upon the consumer or a loss of profit to the producer. Moreover, under visual grading it has had to be assumed that pieces of the same size and species containing similar visual defects had similar strength characteristics. This is not necessarily so. Variations in aspects such as density, moisture content and hidden defects can make a lesser appearing piece of timber far stronger than an absolutely clear appearing one.²

Improvement of structural lumber's competitive position requires an attack on these problems. Grades must be simplified and structural lumber's actual strength must be determined. Machine stress rating of lumber is the industry's first big step in this direction. With its application, all 162 stress grades (as many as 45 for each of at least 12 species)³ could be consolidated into just three grades (premium, standard, and utility) with seven strength classifications. These would include far greater strength values than are now permitted. Span tables that now fill 46 pages could be condensed onto a single page.⁴ Furthermore, the consumer would know he was getting a product graded to more accurate engineering specifications.

¹Harold E. Worth, "Structural Lumber Grading and Its Implications for the Industry," U. S. Forest Service, U. S. Department of Agriculture (Portland: Pacific Northwest Forest and Range Experiment Station, February 6 & 7, 1961), p. 3.

²J. G. Sunley and W. M. Hudson, "A Report of the Research on the . . . Machine-Grading of Lumber in Britain," Forest Products Journal, XIV (April, 1964), p. 157.

³"Round Table . . .," ,. 132.

⁴Ibid.

CHAPTER III

THE DEVELOPMENT OF MACHINE STRESS RATING

Research in the Lumber Industry

Research has developed slowly in the lumber industry. Part of the explanation lies in the industry's structure. The characteristically smaller firms are individually unable to conduct research programs on the major scale engaged in by firms of competing industries. Another part of the explanation is the attitude toward research, which has improved as competition has become stiffer. More millions have been spent on wood research since World War II than in all previous time.¹ Available on the market now, due to these efforts, are laminated wood, finger-jointed wood, preprimed wood, prefinished wood, shrinkproof wood, plasticized wood, film-surfaced wood, warpproof wood, waterproof wood, fireproof wood, and engineered wood, to mention a few. There are also many combinations of wood with plastic, paper, and metals. Nonetheless, there is great need to expand industrial research in the lumber industry. For example, the lumber industry spent about \$8 million on research both in 1960 and 1962. Standard Oil Company of California spent over three times as much itself in research and technical services in 1960.² In wood products, the softwood plywood industry, whose expenditures in research and development are far below the nation's average,

¹"Round Table . . .," p. 131.

²Fisher, p. 58.

spent about twice as much proportionately on research in 1962 as the lumber industry.¹

More and more men in the lumber industry are coming to realize that if their products are to compete in an age of scientific research and business innovation, there must be devised a way of letting the consumer know exactly what he is getting. In the marketing of structural lumber, this means 100 per cent inspection and accurate labeling of pertinent information. Such a demand has been looked upon with skepticism.² To those who believe that the lumber industry has its limits, Dr. Herbert B. McKean, Director of Research for Potlatch Forests, Inc., offers an example of success in research for another industry. "Today we find 25 per cent of all aluminum production going into construction, but only a few years ago aluminum was regarded merely as a good material for kitchenware and airplanes."³ Today aluminum windows, joists, and studs are realities; so are all-aluminum homes.

Non-destructive Testing of Wood

The movement toward more engineered materials in home construction has depended heavily on non-destructive testing of wood. True non-destructive testing requires assessment of a material's discontinuities and properties in such a manner that the usefulness of the

¹Ibid.

²Herbert B. McKean, "After Lumber . . . What Other Products--Why?," Forest Products Journal, XIII (May, 1963), pp. 180-85.

³Ibid.

specimen is not impaired. Potential methods for non-destructively testing wood include mechanical, radiational, electrical, vibrational, and chemical techniques.¹ Before turning to the presently operational mechanical technique for testing structural lumber's strength, background knowledge of the field of non-destructive testing may provide a framework of understanding for future developments.

As a distinct field of study, non-destructive testing of wood is very young. Products which may eventually be so tested include structural lumber, laminated lumber, fabricated trusses, plywood, edge and end glued items, particleboards, hardboards, and prefinished products.² In recent years, with the developing interest and efforts in research in non-destructive testing, several attempts have been made in the forest products industry to organize the field into a consistent body of knowledge. However, no agreement to date has been achieved on how this should be done.

One alternative proposed by A. S. Gregory, Director of Research of the Weyerhaeuser Company, is to classify testing into areas which have different impacts upon the industry.³ He proposed five such areas:

¹Stanley Pelster, "The Stress-O-Matic Stress Rating System," Symposium on Nondestructive Testing of Wood (Session V - Mechanical Methods; held at U. S. Forest Products Laboratory, Madison, Wisconsin, October 7, 8, 9, 1963; Portland: Western Pine Association, October 10, 1963), p. 5. (Mimeographed.)

²A. S. Gregory, "Objectives, Needs for Nondestructive Testing of Wood," Forest Products Journal, XIV (February, 1964), p. 78.

³Ibid., pp. 77-79.

1. Potential changes in product specifications.
2. Methods of use and markets.
3. Manufacturing processes and controls.
4. Utilization of raw materials.
5. Techniques for research and development.

William L. Galligan, in the Wood Technology Section of the Division of Industrial Research at Washington State University, has suggested several alternatives.¹ One is to classify tests according to the human senses they utilize such as hearing, sight, taste, touch, smell, and reason. Another is to classify by product, be it fibers, particles, veneer, lumber or chemicals. A third is to classify by similarity of test method. The fourth, an approach Galligan applies in his review of the field's current status, is to classify tests according to the properties of the wood with which they are concerned. The major classes are mechanical, physical, and chemical.

Machine Stress Rating

Dynamic growth in applications of non-destructive testing of wood is to be found only in the area of structural lumber grading. This has been made possible through the development of scientific relationships between strength and other mechanically measurable properties of the wood. Because of its unique leadership position in applied industrial research, machine stress rating is being watched with great interest and anticipation throughout the forest products industry.

The development of machine stress rating has been a long battle

¹William L. Galligan, "A Status Report . . . Nondestructive Testing in Wood," Forest Products Journal, XIV (May, 1964), pp. 221-27.

of trial and error. Men in industry and at private and government laboratories have almost invariably reached the conclusion that the test must be able to be applied at the mill and to each piece of wood.¹ Some of the first non-destructive tests for strength properties of structural lumber were over 30 years ago on its specific gravity.² Studies on vibrational characteristics began about 20 years ago.³ A study by Herbert B. McKean and Robert J. Hoyle (Assistant Director of Research, Potlatch Forests, Inc.) in 1959 indicated problems in the successful application of these two methods to characteristics of wood tested by stress rating machines.⁴

Three developments in research into structural characteristics of wood brought about the necessary breakthrough for making machine stress rating a reality. First, thousands of tests disproved a belief that stiffness remains constant regardless of bending strength. On the contrary, there is a close correlation between the two.⁵ Second, thousands of tests disproved the belief that the current maximum stiffness allowed by building codes is valid. Nearly a quarter of all dimension of the higher strength species like southern pine, Douglas fir, and larch safely exceeds this limit and nearly 10 per

¹Worth, p. 3.

²Galligan, p. 224.

³Ibid.

⁴H. B. McKean and R. J. Hoyle, "Stress-Grading Method for Dimension Lumber," Symposium on Timber (Fourth Pacific Area Meeting Papers; ASTM Special Technical Publication No. 353; Philadelphia: American Society for Testing and Materials, 1964), pp. 3-4.

⁵"Round Table . . .," p. 11.

cent exceeds it by almost half again as much.¹ Third, thousands of tests have established a safe margin for error in calculating the stiffness of a joist by testing it as a plank; that is, for judging stiffness due to pressure on edge from flatwise testing pressure.² Machine stress rating was initially studied by the Western Pine Association in a research project seeking a rapid destructive method of locating poorly manufactured finger joints in the production line.³ Rapid mechanical bending tests to determine lumber stiffness developed as an outgrowth from this project.⁴

Two machines, each with its own technique, were designed by independent research groups. While the technique of each for determining structural strength differs, there are similarities between the two. Both systems are based on the behavior of the piece in bending it as a plank.⁵ Both complete the correlation of stiffness to strength so fast that the final ratings can be stamped on each piece of wood before it leaves the machine.⁶ Appendix A provides a technical review of the machine stress rating system.

The CLT (Continuous Lumber Tester) machine was developed by Potlatch Forests, Inc., in collaboration with Industrial Sciences of

¹Ibid.

²Ibid.

³"Stress-O-Matic Stress Rating System Summary" (Research Note No. 5.3322; Portland: Western Wood Products Association, March 1, 1963), p. 1.

⁴McKean and Hoyle, pp. 4-5.

⁵Lyman W. Wood, "Machine-Graded Lumber . . . Out of the Laboratory--into Commercial Trials," Forest Products Journal, XIV (January 1964), p. 42.

⁶"Round Table . . .," p. 132.

Portland. It is referred to as an "electro-mechanical stress tester." Most elaborate of the two machines, it costs approximately \$45,000.¹ It is able to test 8 to 26 foot dimension pieces in widths 4, 6, 8, 10, or 12 inches, and can operate at speeds up to 1,000 lineal feet per minute.² With the unique advantage of "double deflection," the CLT-1 makes mechanical allowance for the fact that very few pieces of lumber are perfectly straight.³ Appendix B provides a technical review of the character and operation of this machine.

The Stress-O-Matic machine was developed by the Western Pine Association in collaboration with Tri-State Machinery Company in Dallas. It costs approximately \$13,050.⁴ Chairman Arthur Temple, Jr., of the National Lumber Manufacturers Association has said, "Even the smallest mill can't afford not to buy one."⁵ It is able to test 8 foot or longer dimension in widths 4, 6, 8, 10, or 12 inches, and operates at constant speeds up to 600 lineal feet per minute.⁶ While not incorporating a technique of "double deflection," the Stress-O-Matic does not appear to produce stress ratings different enough to cause concern. Appendix C provides a technical review of the character and operation of this machine.

¹Ibid., p. 133.

²"Two Stress Grading Machines in Action," Forest Industries, XC (August, 1963), pp. 86-87.

³"The Modern Concept of Lumber Stress Testing and Grading" (Portland: Industrial Sciences, February, 1963), p. 3.

⁴"Model 3572 Stress-O-Matic Lumber Pretester--General Description" (Tri-State Machinery Company, April 1, 1964), p. 2. (Mimeographed).

⁵"Round Table . . .," p. 133.

⁶Letter from Stanley D. Pelster, Tri-State Machinery Company, Dallas, Texas, November 7, 1964.

Mechanical Problems in Machine Stress Rating

Contrary to some claims, machine stress rating does not automate the inspection process. Visual grading is still required to determine the effects of defects occurring up to 4 feet from each end and any existing shake. Neither of the machines can determine the nature of defects or their extent. They can only evaluate the total actual strength of a given piece of wood by means of a non-destructive deflection test. Hence, retesting is possible. For these reasons, stress rating machines are a major improvement over existing grading methods. Still, their imperfections are acknowledged and being watched carefully.

The Federal Housing Administration, which insures loans on private residential construction, has approved the use of machine stress rated lumber on an experimental basis. In the meantime, investigations are being conducted by research technologists at the U. S. Forest Products Laboratory in Madison, Wisconsin, in which the performance of machines in current operation is being studied. According to Lyman W. Wood, in charge of structural research at this federal laboratory, the machines and lumber stress rated by them have been subjected to rigorous laboratory testing. There is still need for observation of the operational capabilities of the machines after they have been subjected to the stresses and high speeds of modern sawmill production lines.¹ For example, when production speed runs at 600 lineal feet per minute, the machine has to stress rate and stamp a 16 foot 2 x 4

¹"Machine Grades Checked," Crow's, XLII (September, 1964).

in only one and a half seconds. While not yet determined, the effects on the machine of operation at such speeds day after day could be significant.¹

The Forest Products Laboratory in Wisconsin has also expressed concern about the particular technique applied by the Stress-O-Matic.² Foreseeing that some of this output is utilized as scaffold planks, possible damage by the machine's technique to pieces that pass the test would have serious consequences. Hence, safety devices and exceptional controls have been a must in laboratory work developing the machine to guarantee that such damage was minimized or did not occur.³

In a series of four certification tests approved by the Laboratory, strength values of structural lumber were determined by use of both the CLT-1 and the Stress-O-Matic. A few of the runs of lumber did not meet one "f" value minimum requirement. However, upon adjustment of the machine, Mr. Wood pointed out, this requirement was met.⁴

Visual grading is desired by some operators to catch edge defects that may have a greater effect in the board's use as a joist than on its behavior in flatwise flexure by the machine.⁵

These problems are real and should be improved in the future refinement of machine stress rating. There is confidence that this

¹Ibid.

²Wood, p. 42.

³Ibid.

⁴Letter from Lyman W. Wood, in Charge, Structural Utilization Research, Division of Wood Engineering, U. S. Forest Products Laboratory, Madison, Wisconsin, "Enclosed summary of certification tests, February 11, 1964," October 20, 1964, p. 1.

⁵Wood, "Machine-Graded Lumber . . .," p. 42.

will be done.¹ The stress rating machines show greater possibilities for accurately measuring true strength potentials of structural lumber than any other existing method.²

Technology Affecting Machine Stress Rating

Technology is playing a major role in the impact of the stress rating machines upon marketing of structural lumber. By allowing an improvement over the existing visual stress grading method, technology has created a demand for stress rating machines. By limiting the functions of the machines and suggesting potential methods that may be superior to the stress rating machines, technology has limited this demand.

Several studies for improving the stress rating machines are underway. There is a need for developing a method to stress rate up to 4 feet from each end of the stock currently machine stress rated. Efforts are being made in a number of laboratories to devise a mechanical device with this ability.³ An area in which several studies have been conducted, but in which there needs to be much work done, is the verifying of the correlation used to determine the strength of structural lumber by machine methods. In comparing results of three studies, William L. James of the U. S. Forest Products Laboratory in Wisconsin

¹Ibid., p. 43.

²C. T. Mahaffey, "A Review of Technical Provisions in the Proposed Changes to the Current ALS SPR 16-53" (Washington, D. C.: National Bureau of Standards, 1964), p. 53.

⁴Wood, "Machine-Graded Lumber . . .," p. 43.

suggested that species and grade may affect these equations.¹ He found that different equations were derived when clear Douglas fir, mixed grades of Douglas fir, and clear sugar maple were tested. There is also concern that the effects of varying moisture contents on stiffness and strength characteristics of structural lumber may further complicate the correlation equations. Lyman W. Wood stated in 1964 that, within the industry, consideration is being given to the possibility of edgewise rather than flatwise bending by the machine.² At the same time he said that another project is the development of machines that will predict shear as well as other strength properties.³

While not yet operational, vibrational methods for determining the strength of structural lumber appear more and more possible. Dr. George G. Marra, Director of the Wood Technology Section of the Division of Industrial Research at Washington State University, maintained that such methods would be superior and outdate the stress rating machine when they become operational.⁴

Efforts toward the development of stress rating machines are not limited to institutions in the United States. The Forest Products Research Laboratory of Great Britain has been working for several years on a "mechanical stiffness tester" for rating the strength of structural

¹William L. James, "Vibration, Static Strength, and Elastic Properties of Clear Douglas-Fir at Various Levels of Moisture Content," Forest Products Journal, XIV (September, 1964), pp. 409-13.

²Wood, "Machine-Graded Lumber . . .," p. 43.

³Ibid.

⁴George G. Marra, Talk at the Montana State University School of Forestry, February 25, 1965.

lumber.¹ The Forest Products Laboratories of Canada have also studied the problem and plan to install two machines on an experimental basis.²

Because of the success of machines in the stress rating of structural lumber, steps are being taken to adapt the machine to stress rating stock for glued laminated beams.³ As well, some testing has been done on $2\frac{1}{4}$ x 6 decking consisting of three 1 x 6 boards face laminated to make glued laminated decking. The results from studies thus far have been encouraging.⁴

The possibilities for the stress rating of plywood by machine have been outlined by David R. Countryman, assistant technical director for research and engineering of the Douglas Fir Plywood Association.⁵ The Forest Products Journal reports that the stress rating machines can only supplement and not supplant conventional methods in this area.⁶ The Douglas Fir Plywood Association has not proposed to develop a stress rating machine for plywood suitable for mill use because of this weakness, although it will cooperate with others who may want to develop such a machine.

¹Sunley and Hudson, pp. 155-58.

²Wood, "Machine-Graded Lumber . . .," p. 42.

³Pelster, "The Stress-O-Matic . . .," p. 5.

⁴Ibid.

⁵D. Countryman, "Plywood as an Engineering Material," Symposium on Timber (Fourth Pacific Area Meeting Papers; ASTM Special Technical Publication No. 353; Philadelphia: American Society for Testing and Materials, 1964), pp. 28-37.

⁶Forest Products Journal, XIV (January, 1964), p. 14A.

⁷Ibid.

CHAPTER IV

THE MARKETING OF MACHINE STRESS RATED LUMBER

Acceptance by Industry and Government

Insuring the public of reasonable safety in home construction and other structural uses of dimension presents an enormous task. The capabilities of structural lumber must be both measurable and related to standards relevant to final utilization. Furthermore, there must be a universal means of applying comparable standards to all species and qualities of dimension, and these presented in terms understood by producers, marketers, and consumers. Finally, the cost of such a function must be feasible.

The industry has attempted to keep this regulatory function under their own, rather than the government's, control as much as possible. Associations have been established throughout the country to apply uniform standards to products of a particular region. It was one of these, the Western Pine Association (now the Western Wood Products Association) that was chiefly responsible for the development of the Stress-O-Matic.

Even with careful controls established by private associations, government checks have been necessary. The Federal Housing Administration, for example, must give its consent to building materials used in residential construction under its coverage. Moreover, innumerable building code authorities, both local and regional, exist throughout the country. Machine Stress Rating, in offering an alternate method

of stress rating structural lumber to visual grading, has had to come under the scrutiny of these regulatory agencies. Some have offered 100 per cent support, some have offered partial support, and others are still hesitant to recognize this new development.

Research and engineering calculations for machine stress rating were completed in 1960.¹ By 1961 the machine design for the CLT-1 was perfected and by 1962 so was that for the Stress-O-Matic.² According to Lyman W. Wood, "The U. S. Forest Products Laboratory reviewed the data supporting the two machine-grading systems, both from the lumber industry research laboratories and from other sources. Following that review, lab specialists gave their opinion in 1962 that both systems showed enough promise to justify production and use of light-framing lumber in houses on a trial basis, where it could be observed and could begin to develop a service record."³ Confirmation of the research and engineering calculations for machine stress rating was received from the National Association of Home Builders.⁴ On January 1, 1963, the Western Pine Association's formal acknowledgment of machine stress rating became effective,⁵ and the initial marketing

¹"Round Table . . .," p. 133.

²Ibid.

³Wood, "Machine-Graded Lumber . . .," p. 42.

⁴"Round Table . . .," p. 133.

⁵"Mechanical Stress-Rated Lumber" (Interim Span Tables and Table of Allowable Stresses for Mechanical Stress-Rated Lumber; Washington, D. C.: Federal Housing Administration, May 1, 1963), p. 188591-P.

of machine stress rated lumber began.¹ Since then the Western Pine Association and other machine stress rating advocates have been presenting this system to the principal model building code authorities, the Federal Housing Administration, engineering societies, and other organizations important to the industry.²

Through these efforts, many local building code authorities now permit the use of machine stress rated lumber.³ Regional code agencies are considering the system, but thus far only the Southern Building Code authority has recommended its use and acceptance.⁴ According to a Western Wood Products Association Research Note,⁵ the City of Los Angeles has granted its acceptance.

A technique developed in the Northwest, machine stress rating of structural lumber has been supported predominantly by the Western Pine Association and the West Coast Lumberman's Association (now combined into the Western Wood Products Association), spokesmen for this region. In order to offer a more reliable product, the inspection bureaus of both groups prepared manuals which provided for initial and periodic inspection of the machines, inspection of the lumber stress rated by them, and authorization to use copyrighted bureau

¹Robert J. Hoyle, Jr., "Electro-Mechanical Stress Grading of Two-inch Structural Lumber" (American Society of Agricultural Engineers; Lewiston, Idaho: Potlatch Forests, Inc., 1963), p. 13.

²"Stress-O-Matic . . .," p. 7; Hoyle, p. 13.

³Hoyle, p. 13.

⁴"Round Table . . .," p. 133.

⁵"Stress-O-Matic . . .," p. 7.

grading stamps which can be withdrawn if the machine fails to operate properly.¹

The Southern Pine Inspection Bureau, another regional association, has also accepted machine stress rating. Unfortunately, its machine stress rating supplement to grading rules provides for 11 stress levels for dimension which do not parallel the 9 levels originally established by the Western Pine Association.² Under the direction of the SPIB, the southern pine lumber industry is studying the possible application of machine stress rating to their own species.³

On May 1, 1963, the Federal Housing Administration issued a release which allowed the use of machine stress rated lumber in residential housing.⁴ However, its acceptance was only partial.⁵ The amendment provided for machine grading on an interim basis with only provisional joist and rafter span tables, pending further study of the machine's operation.⁶ The U. S. Forest Products Laboratory, under the direction of Lyman W. Wood, was assigned the task of testing samples of run-of-production lumber graded by both machines. To get this material, the Laboratory engineers are collecting their samples, not at sawmills, but at plants or yards to which the lumber was shipped

¹Wood, "Machine-Graded Lumber . . .," p. 43.

²"Round Table . . .," p. 129.

³Wood, "Machine-Graded Lumber . . .," p. 43.

⁴"Mechanical Stress-Rated Lumber," p. 188591-P.

⁵Wood, "Machine-Graded Lumber . . .," p. 43.

⁶Letter from Wood, p. 2.

for use. The Federal Housing Administration believes it desirable now, while relatively little dimension is being so graded, to conduct this check on the consistency with which the machines are doing the job.¹ That is why the engineers are going to locations where the lumber is being used, rather than to mills where it is being produced and graded.

The Laboratory engineers obtain their samples by sorting through piles of lumber on a statistically random basis. Samples chosen are purchased from the plant owner and shipped to the laboratory for evaluation and analysis. Samples are being collected at Lafayette, Indiana, and Elmira, New York, plants of National Homes, Inc., America's largest builder of factory assembled home components, and at the Peter Kuntz Lumber Company in Dayton, Ohio.² Upon arrival at the laboratory, the lumber will be visually graded by an industry certified grader who does not know the machine grade. The lumber's stiffness will be tested then as will its total strength capacity. Data thus obtained will furnish a basis for determining how closely the original stress rating assigned by machine at the sawmill compares with grades determined by long-established conventional procedures, and how the rated stress compares to actual breaking strength.³

Acceptance by the Federal Housing Administration is considered vital to the machine's acceptance in the industry. Robert F. Schmitt, past chairman of the National Association of Home Builders, has pointed out, "Until FHA disseminates a bulletin to its field offices saying

¹"Machine Grades Checked."

²Ibid.

³Ibid.

that machine grading and the accompanying grading rules and span tables are acceptable we can't get anywhere. Without FHA the lumber mills can't sell machine-graded lumber anywhere, so how can the mills afford to buy the machinery?"¹ Moreover, an article in House & Home claims that the lumber manufacturers expect little code trouble after the Federal Housing Administration has taken the lead.²

Another organization interested in the development of stress rating machines is the American Society for Testing Materials, which has appointed a task group, under its Committee D-7 on Wood, to study the two machines.³ The objective is to eventually develop an ASTM standard.

To further acceptance of machine stress rating in the marketing of structural lumber, pressure groups are forming. One of these was a "Round Table" sponsored by the National Lumber Manufacturer's Association and Time, Inc.'s magazines (e.g., Architectural Forum, House & Home). It initially met in July, 1960, to start collaboration between the lumber industry, housing industry, and paint industry. In March, 1963, it met a second time, having expanded and fathered together leaders of all the important lumber trade associations and those of all the housing industry trade associations. At this second meeting the Round Table, concerned generally with improving the engineered use of wood, dealt at length with the problems facing acceptance

¹"Round Table . . .," p. 133.

²Ibid.

³Wood, "Machine-Graded Lumber . . .," p. 43.

of machine graded dimension. A report on the meeting and developments in the months immediately following correlates much of the latter to the efforts of the Round Table.¹

Industrial Application

Production of machine stress rated lumber has so far been entirely in the western states.² Latest figures as of November 7, 1964, indicated at least 100 MMbf of dimension had been stress rated by machines thus far in 1964.³ The bulk shipped for commercial use was white fir 2 x 4's for trussed rafter construction, according to Lyman W. Wood.⁴

There were 18 to 20 stress rating machines, Stress-O-Matics or CLT-1's, in use by November of 1964, with only about half of them producing a significant volume of machine stress rated lumber.⁵

Several experimental projects have been undertaken utilizing machine stress rated dimension.⁶ A National Association of Home Builders research house was built with machine stress rated joists at Rockville, Maryland, in 1962. Several houses using machine stress rated dimension in trussed rafters were erected in the Denver and

¹"Round Table . . .," p. 129.

²Wood, "Machine-Graded Lumber . . .," p. 42.

³Letter from Pelster, p. 1.

⁴Wood, "Machine-Graded Lumber . . .," p. 42.

⁵Letter from Pelster, p. 1.

⁶Wood, "Machine-Graded Lumber . . .," p. 42.

Salt Lake City areas soon after.

While machine stress rating is still a relatively new development, observations are being made by those using it. One of the first to make use of stress rating machines, George Flanagan of Elk Lumber Company, Medford, Oregon, claims that the machine helped put the company back into the dimension business.¹ He points out, however, that the appearance still plays a major role to the consumer and consequently much material that passes the machine's test must be visually downgraded.² He says, "The machine will never replace the grader. The grader uses the machine's findings, adds what he can see and arrives at the final grade."³ For example, he has found that a piece might have so much wane that it might not give sufficient bearing surface; yet that same piece might be strong enough to make the grade mechanically.⁴ The company is using the Western Pine Association's Stress-O-Matic. The machine is set on the offbear side of a (Woods 414M 10 knife) planer, adjusted to a permanent lineal speed of 400 feet per minute. In operation, the machine is fed by power rolls. At the other end, the stamped pieces drop onto the grading table ahead of the sorting chain for visual grading. The machine is mounted on wheels and can be rolled out of the way when not in use. A power roll section is rolled into its place to carry the stock from the planer to the sorting

¹"Machine Stress Grading Fits Lumber to Better do its Job," Forest Industries, XC (August, 1963), p. 38.

²"Two Stress Grading Machines"

³"Machine Stress Grading," p. 38.

⁴Ibid.

chain. Western Pine inspectors check the unit regularly. All settings are sealed between inspections. It is claimed that a drop in air-supply pressure is the only malfunction which could affect the machine's accuracy.¹ If this happens, the feed rolls lock and the machine becomes inoperative.

In 1963, an Industrial Science's CLT-1 was installed in the Frank Lumber Company's planing mill at Mill City, Oregon. Here, too, poor appearing material was downgraded or rejected on a visual basis even though its structural soundness was approved by the machine's test. The product has been marketed under the trade name of "Vis-Mac" to denote both the visual and mechanical aspects of the grading procedure. The sales manager for the company forecasts that the improved engineering standards will strengthen the position of the forest products industry in competition with other building materials.² The company produces about 200 Mbf of dimension daily, approximately 70 per cent west coast hemlock and 30 per cent Douglas fir, all kiln dried.³ The Clt-1 is fed material from the planer via a belt hinged so that it may be lifted at one end, to permit the option of dropping rerun from the planer directly to the sorting chain. Hence, the machine did not need to be mobile. The West Coast Lumberman's Inspection Bureau supervised grading.

A planing mill in Colorado has used a Stress-O-Matic to grade

¹"Two Stress Grading Machines"

²"Mechanical, Visual Grading Offer Combined Advantages," Forest Industries, XCI (September, 1964), p. 97.

³Ibid.

lodgepole pine dimension. It finds that some ponderosa pine not suitable for cut stock can be stress rated as dimension with good financial return.¹

Stress-O-Matic machines are being used by Weyerhaeuser Company in a variety of ways. Two machines stress rate dimension to be used for laminated decking. Their operation differs from conventional Stress-O-Matic use in that the piece is machine stress rated flatwise and loaded flatwise in use. Consequently, there is no need to correlate flatwise with edgewise stiffness. Another machine is being used on 2 x 4's and 2 x 6's for west coast hemlock trussed rafter stock. The technical director claims there is no cost advantage in machine stress rating the decking since visual grading (for appearance only) is still required, and there is little, if any, cost advantage in machine stress rating the rafter stock.² He finds that the machines offer a definite marketing advantage.³ The company has two additional machines being used experimentally. One of these is being tried for L-1, L-2, L-3 grades for laminating stock for large horizontally laminated beams. The second is being developed for testing full size small vertically laminated beams up to nominal 6 x 12 inch size in lengths up to 60 feet.

Demand from the Market

A market survey of demand for machine stress rated lumber apparently has yet to be made, probably because machine stress rated lumber

¹Letter from Pelster, p. 1.

²Letter from Williston, pp. 1-2.

³Ibid.

has not been given adequate chance to enter the market. The industry has been hesitant to accept this development due to reservations held by the building code authorities and the Federal Housing Administration. Still many important advantages of machine stress rated lumber are already apparent.

Stress rating machines visually supplemented take the guesswork out of stress rating structural lumber, thus offering far greater accuracy than previously existing methods used to obtain stress values. Retesting is made possible because the test is non-destructive. Now the consumer can be sold lumber with the strength he wants. Machine stress rating does not penalize lumber for the necessary shortcomings that are inherent in visual grading. For example, the allowable stress for a given visual grade is determined on the basis that a maximum knot size is present in every piece in the grade. Actually the maximum knot or defect is rarely in every piece, probably less than 5 per cent of them in most cases.¹ Also, density is an important factor in allowable stress and stiffness, but ring count and per cent summer wood are difficult to determine visually, and even so, these criteria are not indicative of density in every case.² Another example of visual grading's shortcomings is the relation of knot defects to density. While knots receive greater attention, the presence of a properly placed tight knot can have much less influence on strength than

¹Stan Pelster, "Machine Stress Rating with the Stress-O-Matic" (Spokane: Northwest Wood Products Clinic, April 22, 1964), p. 1. (Mimeographed).

²Ibid.

does wood's density.¹

Many of the specifiers and consumers have been reluctant thus far to give up the large factor of safety (100 per cent to 500 per cent margins²) now existing in most of the dimension graded visually.³ They must be educated to rely upon the assigned rating and not just the visual appearance of the stock. Dealers now sell lumber products primarily on the basis of appearance because the public has become accustomed to relating strength to an absence of knots or other types of visible defects. There are actually many applications where lumber of poor appearance does a fine job. These markets can be satisfied with appropriate material if its quality is based on actual strength measurement. Nonetheless, it appears that many consumers will be hard to move from these current practices.⁴

Inherent in the greater accuracy of machine stress rating is the actual measurement of stiffness of each piece of wood in determining the piece's structural capacity. The need for grouping pieces and using a minimum strength value is eliminated. With both the stiffness and the strength of each piece known, stock for a particular task is more nearly the same. Less deflection of individual joists and trusses results with flatter floors and roofs.⁵

¹Gregory, p. 78.

²"Round Table . . .," p. 132.

³Wood, "Machine-Graded Lumber . . .," p. 43.

⁴"Stress-O-Matic . . .," p. 7.

⁵"Simpson EMSR Structural Lumber Manual" (A.I.A. File No. 19-B, Simpson Timber Company), p. 502.

Greater precision in strength measurements makes structural lumber better suited to today's sophisticated and exacting structural designs requiring the best possible knowledge of strength properties of building materials. Hence, structural lumber's competitive position in the modern construction market is improved.

Test samplings have found that 75 per cent of the Douglas fir classified "Construction" by visual grading is actually at least 10 per cent stronger than the requirement for "Select Structural" and 50 per cent of this material is over 40 per cent stronger.¹ Test samplings have found also that 75 per cent of the western larch now classified "Construction" is at least 20 per cent stronger than the present requirement for "Select Structural" and 50 per cent of this material is over 55 per cent stronger.² Acknowledgment by the housing industry of structural lumber's actual strength, previously hampered by excessive safety margins and inaccurate, underrating stress tables, will permit two alternatives in its future use. Machine stress rated lumber can be used in a structural job requiring greater strength or it can be used in the same job in smaller pieces.³ For example, longer spans in trusses, joists, and rafters are possible and the allowable load capacity in columns and as compression members can increase. It is claimed that machine stress rating will at least double the availability of the stronger grades of lumber.⁴ This would make possible new ways of building and open up new markets that could exploit the selection of increasingly large volumes of high strength

¹"Round Table . . .," p. 132.

²Ibid.

³Ibid.

⁴Ibid.

materials.¹ There are also advantages in using machine stress rated lumber for the same structural job done by visually graded lumber. The smaller sizes of machine stress rated lumber, offering comparable strength, reduce the necessary depth of floor joists and ceiling joists.² The ultimately possible smaller over-all height of a building not only could result in savings on lumber costs, but also of siding, brick, or other expensive facing and paneling materials.³

Machine stress rating proves that some species of wood that have not been used in stress construction because their strength ratings were thought to fall below the minimum construction standards are much stronger than the existing ratings assume.⁴ They will now compete with the presently acceptable species. For example, it is claimed that only with the use of the machines to determine the stress ratings of lumber have producers of white fir and inland Douglas fir been able to enter competitively the dimension structural lumber market.⁵ This market in the past was dominated by producers in the Douglas fir subregion and to some extent southern pine producers.⁶

Machine stress rating offers increased speed in the processing

¹Gregory, p. 78.

²"Simpson EMSR Structural Lumber . . .," p. 502.

³Ibid.

⁴Statement of Aaron U. Jones, Seneca Lumber Company, Eugene, Oregon, Chairman, West Coast Lumber Inspection Bureau, p. 2.

⁵Letter from Wayne W. Gaskins, Western Forest Industries Association, February 17, 1964, p. 3.

⁶Ibid.

of structural lumber. While visual grading is still an important function in the grading phase, its task is less time consuming with the aid of the machine.¹

Machine stress rating does not base its test on wood's environment in growth and, hence, eliminates the need for keeping data on the origin of each piece of wood.² For example, Douglas fir grows over wide areas and traditionally has been divided into two or more geographic classes of working strength. Southern pines include four major species with differing strength values and yet under visual grading they have been considered as one strength group. A similar situation exists among western true firs. Another example is Engelmann spruce from Canada, which has been given a higher grade than the same species from the United States.³ Machine stress rating also makes unnecessary separate data in span tables for different species and variations in spans according to species.⁴ For example, for a given span and spacing, visual grading permits use of a 2 x 6 of Douglas fir, but requires a 2 x 8 of pine. As well, a substantial simplification of the variety of grades and grade names offered to the consumer becomes possible.⁵ This would help structural lumber's position with engineers who avoid using lumber because of the

¹"Potlatch EMSR Structural Lumber Manual" (A.I.A. File No. 19-B-3, Potlatch Forest Industries, August 1, 1963), p. 4.

²"Stress-O-Matic . . .," p. 1.

³Wood, "Machine-Graded Lumber . . .," p. 42.

⁴"Potlatch EMSR Structural Lumber . . .," p. 4.

⁵Hoyle, p. 13.

complexity of the grades. This also means simplified lumber ordering to the retailer and distributor.¹ Equally important, it permits reduced inventories without sacrifice of ability to fill every need.

With its identification of high-strength material not detected by visual grading, machine stress rating insures maximum strength utilization. This economy improves both value to the customer and realization to the manufacturer, and provides architect, engineer, builder, and specifier with more exact standards of dependability.² According to a release from Potlatch Forests, Inc., "Perhaps no development in the history of the modern lumber industry--from the manufacturer through the retailer--is as important as high speed, automatic stress-rating for precise strength of structural lumber. But the benefits pass on to designers and builders using lumber products . . . and ultimately to the end consumers, the buyers of end products built of lumber."³ The consumer gains reduced overall costs and better planned houses with more open designing allowed and with less lumber doing more and better work.⁴

Machine Stress Rating in a Dynamic Market

Machine stress rating of structural lumber has passed through the laboratory stage and entered the stage of operation and trial. This will be its most critical stage. On the one hand, laboratory

¹"Potlatch EMSR Structural Lumber . . .," p. 4.

²"The Modern Concept of Lumber . . .," p. 2.

³"Potlatch EMSR Structural Lumber . . .," p. 4.

⁴Ibid.

control is replaced by the pressure and tempo of modern lumber production. On the other hand, reaction to this new development, both from within and without the industry, changes from a passive to an active nature.

A small war is brewing in the dimension industry in expectation of machine stress rating's impact.¹ Already this war has involved machine stress rating in major issues that have split the lumber industry for years.² Whatever the outcome of these issues, it is apparent that machine stress rating is playing a major role.³

For years the industry has sought to simplify marketing of lumber by establishing standard sizes and grades throughout the country. Because green lumber shrinks as it dries, the size of lumber can be accurately expressed only in relation to its moisture content. Consequently, there developed a proposal (A Proposed Revision of SPR 16-53 ALS for Softwood Lumber⁴) to separate sizes into two classes of moisture content. "Dry" lumber was to have a moisture content not greater than 19 per cent. "Green" lumber was to have a moisture content over 19 per cent. To compensate for the eventual shrinkage of green lumber, a smaller thickness when shipped was proposed for dry lumber. For example, green dimension was to have a thickness of 1-5/8 inches, while

¹Gerry Pratt, "Lumber War Brews over Two-by-Four," The Sunday Oregonian (March 15, 1964). (Reprint).

²Fisher, p. 3.

³Ibid.; Pratt.

⁴"A Proposed Revision of Simplified Practice Recommendation 16-53 American Lumber Standards for Softwood Lumber" (Washington, D. C.: USCOMM-NBS-DC, 1964), pp. 1-36.

dry dimension would be seasoned and surfaced to a standard $1\frac{1}{2}$ inches.

The "Proposed Revision" was rejected by the U. S. Department of Commerce in 1964, due to results of a nationwide questionnaire showing that the split in the industry over this issue prevented a large enough majority to justify enactment of it.¹ Consequently, both green and dry lumber have continued to have an identical size standard when shipped.

Many leaders in the industry fail to see the relationship of machine stress rating to lumber sizes and the "Proposed Revision."² Nonetheless, it is quite possible that the "Proposed Revision" could have been accepted had the impact of machine stress rating not caused a substantial faction to oppose it.³ Efforts to develop machine stress rating of structural lumber have been in part to correct the under-rating of lumber's strength capabilities. In doing this, machine stress rating upgraded not only existing structural lumber, but weaker stock heretofore graded below minimum construction standards. Much of this latter supply is now valuable for stress construction and hence competes with the former.⁴ Examples of weaker stock are the "Intermountain" or inland species of Douglas fir and white fir particularly, lodgepole pine, Engelmann spruce, and even second or third

¹Letter from John P. Eberhard, Deputy Director, Institute for Applied Technology, National Bureau of Standards, Washington, D. C., October 2, 1964, attachments.

²Letter from Williston, p. 2; letter from J. H. Carr, Jr., Secretary, American Lumber Standards Committee, Washington, D. C., October 19, 1964, p. 1.

³Pratt.

⁴Statement of Jones, p. 2.

growth ponderosa pine.¹

Size is a determinant of the strength of wood. Should sizes of structural lumber be reduced through the "Proposed Revision," once again the weaker species would fall below minimum construction standards. Lumbermen producing the weaker species want to keep the new market and hence opposed the acceptance of the "Proposed Revision."² They claim their entrance into the construction market will lower the price of lumber to the consumer and enlarge "our critical supply of construction timber."³ They claim that producers of the stronger species support the "Proposed Revision" in part because it would eliminate competition from the producers of weaker stock. Lumbermen in support of the "Proposed Revision" claim that the weaker species will not be affected by a reduction in the size of dry lumber.⁴ If a species shipped as green lumber can meet the standards, they claim, so can the same species after it has been dried to a smaller size because the strength and stiffness lost by shrinking to a smaller size is almost exactly offset by the strength and stiffness gained in drying.⁵

Whether the reduced sizes in the "Proposed Revision" ever become standard for dry lumber or not, dry lumber manufacturers are already

¹Pelster, "Machine Stress Rating . . .," pp. 1-2; letter from Gaskins, p. 1; statement of Jones, pp. 2-3.

²Statement of Jones, p. 3.

³Ibid.

⁴"Round Table . . .," p. 132.

⁵Ibid.

switching to it as a non-standard size. P. I. Prentice¹ claims that, with the reduced sizes of dry lumber available, cheaper to purchase and market but just as strong as their equivalent green lumber stock, standard size dry lumber cannot maintain its market.

This war in which machine stress rating has come to play a major role illustrates the kind of forces new developments may have to face in a dynamic market. Often, as is the case thus far with machine stress rated lumber, the effects of such forces upon the product's market potential are not immediately apparent.

Case Studies on Machine Stress Rating

Two lumber companies were selected as case studies. Both have purchased a stress rating machine and installed the machine locally, allowing personal contact for data and observation.

CASE STUDY NO. 1.

Anaconda Forest Products, Bonner, Montana

A. Operations. The company processes about 109 MMbf of lumber annually. About 36 MMbf of this is "Utility and better" dimension, all of which is cut to two inches in nominal thickness and suitable for machine stress rating. This dimension is about 60 per cent Douglas fir and 40 per cent larch. There are two complete processing lines.

B. Machine Stress Rating. A Stress-O-Matic stress rating machine

¹Letter from Perry I. Prentice, Vice President, Time, Inc., Moderator for Round Table on the Engineered Use of Wood, June, 1963. Enclosed speech before the Western Forest Industries Association, San Francisco, April 25, 1964, p. 5.

was purchased in the fall, 1963. In-place costs were itemized as follows:

\$13,180.00	Stress-O-Matic, infeed conveyer, and electric counter.
233.43	Freight.
<u>21,405.73</u>	Installation.
<u>\$34,819.16</u>	Total in-place cost.

The Stress-O-Matic is installed off the production line following the planer. Material may be dropped out to the stress rating machine via an infeed conveyer and is returned to the production line after proceeding through the machine. Operation costs to date have been minimal (probably no more than \$100) due to the machine's intermittent operation. Richard D. Schmautz, the general processing foreman, believes operating costs incurred in the processing of machine stress rated lumber are little more than those incurred in visually grading lumber. The infeed conveyer eliminates extra handling in feeding the machine. The planer's output varies from 400 lineal feet/minute for 12 inch dimension to 600 lineal feet/minute for 4 to 6 inch dimension. Processing speed is limited to a maximum of 400 lineal feet per minute when operating the Stress-O-Matic. Orders on machine stress rated lumber are predominantly for 4 inch wide lumber, and hence processing speed is usually less when machine stress rating lumber than that when visually grading.

- C. Marketing. Most machine stress rated lumber is being marketed for construction of pre-fabricated and component housing under Federal Housing Administration regulations. Brokers are located

in Missoula, Montana, and Chicago, Illinois. The lumber is shipped to Sleepy Eye and Minneapolis, respectively, in Minnesota. Only the Chicago broker has a steady market for the lumber, and even this is small. From Minneapolis, his lumber moves generally to the Chicago area and Indiana. Average production and shipping is about 40 Mbf per month. No inventory is kept at the plant.

Machine stress rated lumber brings about \$10 more per Mbf than visually graded lumber, according to Merrill Lash, the sales manager. He says the market for machine stress rated lumber is still weak and often limited to 4 inch width and specified longer lengths, rather than random lengths. Filling these orders necessitates an excessive amount of shorter lengths to market, which is usually difficult to do.

A sample of 2 x 4 14'-16' Douglas fir and western larch was processed on March 10, 1965, and visually graded as follows:

<u>Grade</u>	<u>%</u>
Construction	51.6
Standard	18.1
Utility	26.8
Economy	<u>3.5</u>
Total	100.0

Richard D. Schmautz believes the percentages in the above sample are roughly typical of visually graded 2 x 4 14'-16' Douglas fir and western larch. On March 3, 1965, a sample of 2 x 4 14'-16' Douglas fir and western larch was machine stress rated as follows:

<u>Machine Stress Rating</u>	<u>%</u>
2100f	49.5
1800f	2.5
1500f	20.8
1200f	13.9
900f	6.4
rejects	<u>6.8</u>
Total	99.9

Mr. Schmautz believes the percentages in the above sample are roughly typical of machine stress rated 2 x 4 14'-16' dimension. He can offer no explanation for the peculiar but consistently low percentage in the 1800f rating. While the data are not suitable for a scientific relationship, it is worthwhile to note what they suggest. The 1965 Western Lumber Technical Manual stipulates that 1900f is a comparable "f" rating for 2 x 4 Douglas fir and western larch dimension visually graded as "Select Structural."¹ Since "Select Structural" is superior in strength quality to "Construction," material having a rating greater than 1900f should be more valuable than the latter. About 50 per cent of the March 3, 1965, sample meets this criterion.

CASE STUDY NO. 2

Intermountain Lumber Company, Missoula, Montana

- A. Operations. The company processes about 82 MMbf of lumber annually. About 25 MMbf of this is Douglas fir and white fir suitable for machine stress rating. To date only Douglas fir

¹1965 Western Lumber Technical Manual (A.I.A. File No. 19-A; Portland: Western Wood Products Association, 1965), pp. 28-29.

has been machine stress rated. There are two complete processing lines.

- B. Machine Stress Rating. A Stress-O-Matic stress rating machine was purchased in August, 1963. In-place costs were estimated as follows:

\$9,300.00	Stress-O-Matic, electric counter, stamp roll spare, freight.
<u>150.00</u>	Installation.
<u>\$9,450.00</u>	Total in-place cost.

The machine is located in a building separate from the planer. Material to be machine stress rated must be transported by carriage and hand fed to the machine. A feed man and tail men are required to move and visually grade the material. Interruption of the continuous flow of operations and excessive handling increase operation costs of lumber machine stress rated about \$10/Mbf. The machine does not follow the planer because no dropout, or infeed conveyer, was purchased to separate material to be machine stress rated. The planer's output of dimension is generally about 450 lineal feet/minute. The output of the stress rating machine is between 200 and 250 lineal feet/minute, due to the manual feeding. Near future plans include purchase of an infeed conveyer which would allow in-line operation.

- C. Marketing. Most machine stress rated lumber is being marketed for construction of pre-fabricated and component housing under Federal Housing Administration regulations. Brokers are located in Missoula and Billings, Montana, Denver, Colorado, and Iowa. The lumber is shipped to Great Falls and Helena, Montana, Denver,

and Iowa, respectively. Average production and shipping is about 20 to 25 Mbf per month. No inventory is kept at the plant.

Michael J. Sullivan, in the sales department, claims that the additional operating costs incurred in machine stress rating lumber make orders for visually graded lumber preferable to those for machine stress rated lumber. Furthermore, he says, sizes of lumber specified by those preferring machine stress ratings are needed to supplement visually graded orders for boards, the company's major product. Mr. Sullivan claims there is a strong market for machine stress rated lumber, due to such advantages as the 50 per cent saving gained by often replacing 2 x 6 visually graded trusses with machine stress rated 2 x 4's.

Mr. Sullivan approximates the visual grades of 2 x 4 random lengths of Douglas fir to be as follows:

<u>Grade</u>	<u>%</u>
Construction	60-65
Standard	20-25
Utility	12-15
Economy	5

He approximates the "f" ratings of machine stress rated 2 x 4 random lengths of Douglas fir (Utility and better) to be as follows:

<u>Machine Stress Rating</u>	<u>%</u>
2100f	32
1800f	18
1500f	30
1200f	15
(Economy)	<u>5</u>
Total	100

While not suitable for a scientific relationship, Mr. Sullivan's data suggest that from 32 to 50 per cent of the visually graded material may have an "f" rating of 1900f or better and hence can be upgraded to "Select Structural."

CHAPTER V

CONCLUSION

Outlook for Machine Stress Rated Lumber

Stress rating machines are designed to process nominal two-inch structural lumber. This product is consumed predominantly in residential construction. Demand for structural lumber in residential construction is a function of the actions of architects, building code authorities, engineers, contractors, builders, and financial agencies, among others, as well as consumers of housing. Assuming the influence of these groups in the future will continue along past trends and demand for residential construction greatly increases as a result of the increasing rate of potential buyers and economic growth, demand for structural lumber should increase. There are trends in the housing industry from heavy construction to light construction, which generally involves more use of structural lumber, and toward increasing the average size of units. The increasing demand for structural lumber is lessened to some degree by trends of a decreasing amount of lumber used per dwelling unit and greater proportion of multi-unit structures being built (tapering in recent months), which require less lumber per unit. Products competing with structural lumber in residential construction consistently have been promoted more aggressively and this is likely to continue. Within the structural lumber industry, American suppliers can expect greater competition from Canadian suppliers.

Development of machine stress rating has been the first major

application of technical studies in non-destructive testing of wood. Men in the lumber industry are realizing more and more the need for research and, should the present trend continue, their proportionate allocation to this function will be greater in the future. This step is a necessity if they are even to maintain their current position in the construction market.

Three characteristics of structural materials of which demand is an important function are reliability of strength, convenience of purchasing, and in-place cost of the product for the job to be done. In these aspects, structural lumber can now be greatly improved due to the development of stress rating machines.

Tests have shown that machine stress rating so consistently stress rates lumber more accurately than visual grading that the latter's excessive safety margins are no longer necessary. The machine's ability to stress rate each piece of lumber individually makes possible the elimination of general downgrading for visual similarities.

Machine stress rating makes possible a simpler, more universal system of stress grades and tables. At the same time, there is also the possibility that machine stress rating, rather than simplifying marketing of structural lumber, can make it more complex by adding another system to the mass of already too complicated spans, sizes, and grades within each species.

Cost advantages are an important contribution of machine stress rating. Marketing, particularly construction, costs can be reduced by using machine stress rated instead of visually graded lumber. The cost savings can be extended to the consumer.

Machine stress rating requires visual grading to detect visible defects which the machine is not able to measure. Laboratories are working to improve the machine's operation in these areas. Machine stress rating with supplemental visual grading offers the most accurate means of stress rating lumber for the near future. The next major development in non-destructive means of stress rating lumber may involve a vibration technique.

The marketing of machine stress rated lumber has begun, and offers savings to producer, builder, and consumer. Sales are confined primarily to markets which can utilize its increased strength values. These markets are generally under Federal Housing Administration authorities, who have only partially accepted the use of machine stress rated lumber. This partial acceptance prevents it from being recognized by most city building code authorities. Until they are willing to recognize machine stress rated lumber, its market will remain limited.

Decision Criteria in Marketing Machine Stress Rated Lumber

With the development of stress rating machines, a new set of alternative processes through which to stress rate two-inch structural lumber becomes available. In determining which alternative is "right", or "best", the decision-maker should satisfy certain criteria. This decision making process may be better understood through an accompanying hypothetical situation.

Realize the Problem. Often much effort is wasted analyzing a minor part of the problem. It may be beneficial to state the problem in the form of a question; such as, "By what means should two-inch

structural lumber be stress rated?"

Formulate an Objective on which to base the solution; such as,
"To get the maximum profit."

Determine Payoff. Payoff is the method used to measure each alternative in determining which most satisfies the objective; such as, "Expected profit in dollars per thousand board feet."

Establish Decision Criterion. The decision criterion provides a means of selecting the alternative whose payoff is most consistent with the objective; such as, "Choose alternative with largest payoff."

After formulating the problem and establishing criteria for its solution, all possible alternatives should be listed; such as:

ALTERNATIVE A: Purchase of a CLT-1.

ALTERNATIVE B: Purchase of a Stress-O-Matic.

ALTERNATIVE C: Do not purchase a stress rating machine.

To solve the problem, the decision-maker must determine the payoff for each alternative. Payoffs may be determined from data on the firm, the firm's environment, and the outlook for the product. If, for example, the payoffs for Alternatives A, B, and C are \$21, \$19, and \$10, respectively, then the solution to the hypothetical problem would be Alternative A. The problem could be presented as follows:

THE PROBLEM: By what means should two-inch structural
lumber be stress rated?

OBJECTIVE: To get the maximum profit.

PAYOFF: Expected profit in dollars per thousand board feet.

	<u>Payoff</u>
ALTERNATIVE A: Purchase CLT-1	\$21
ALTERNATIVE B: Purchase Stress-O-Matic	\$19
ALTERNATIVE C: Do not purchase	\$10

DECISION CRITERION: Choose alternative with largest payoff.

Most problems facing businessmen are more complex than the hypothetical one because they involve more than one estimate of payoffs. For example, the payoffs in the hypothetical problem may be based on a prosperous and expanding economy. The decision-maker may wish to also incorporate into the problem the possibility of a recession occurring which would sharply deter residential construction and suggest changing the determined payoffs for Alternatives A, B, and C, to an estimated \$3, \$4, and \$8, respectively. Another estimate of payoffs may be based on an expected recession but allow for greater acceptance of machine stress rated lumber, in which case payoffs for Alternatives A, B, and C, would be \$8, \$9, and \$5, respectively. All these payoffs could be recognized as follows:

THE PROBLEM: By what means should two-inch structural lumber be stress rated?

OBJECTIVE: To get the maximum profit.

PAYOFF: Expected profit in dollars per thousand board feet.

	<u>Payoff 1</u>	<u>Payoff 2</u>	<u>Payoff 3</u>
ALTERNATIVE A:	\$21	\$3	\$8
ALTERNATIVE B:	\$19	\$4	\$9
ALTERNATIVE C:	\$10	\$8	\$5

DECISION CRITERION: ?

With additional payoffs, the decision criterion should be changed to provide a means of selecting the alternative whose group of payoffs is most consistent with the objective. The hypothetical decision criterion of choosing the alternative with the largest payoff may be satisfactory under one set of conditions, but for most sets of conditions prove unsatisfactory. For example, Alternative A satisfies Payoff 1, but neither Payoffs 2 nor 3. The decision-maker may select a decision criterion favoring the alternative whose payoffs add up to the highest total. On the other hand, he may select a decision criterion that would favor the alternative with the largest minimum payoff, such as Alternative C. These and other decision criteria are discussed in current literature.¹

¹Alfred Oxenfeldt, David Miller, Abraham Shuchman, and Charles Winick, Insights into Pricing (Belmont, California: Wadsworth Publishing Company, 1961), pp. 11-28; David W. Miller and Martin K. Starr, Executive Decisions and Operations Research (Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1960), pp. 79-100.

APPENDICES

APPENDIX A

MACHINE STRESS RATING

Grading by machine has required the development of a new system for rating dimension's strength. The machine measures the wood's stiffness. Research shows a consistent relationship between the stiffness ("E") and breaking strength ("f").¹ This relationship is stamped into the wood as it leaves the machine. Allowable stresses permitted for each relationship have been published by the Western Wood Products Association and the Southern Pine Association.

"E" Grade

Elasticity is a property which can be measured without over-stressing or otherwise damaging wood.² Stiffness is the combined effect of elasticity and cross-sectional size.³ Its value is referred to as the modulus of elasticity, or "E", and is expressed in psi (millions), such as:

E - 1.0
E - 1.8
E - 2.2

"f" Grade

The actual breaking point of a board is referred to as its

¹"Simpson EMSR Structural Lumber Manual" (A.I.A. File No. 19-B: Simpson Timber Company), p. 502.

²Ibid.

³Ibid.

⁴"The Modern Concept of Lumber Stress Testing and Grading" (Portland: Industrial Sciences, February, 1963), p. 3.

modulus of rupture, or "f" (extreme fiber stress in bending) value.¹

"f" values have been used in stress grade marking of visually graded lumber and are expressed in psi, such as:²

900f
2100f
2700f

Allowable Stresses for Machine Graded Lumber

Both stiffness and breaking strength are related to size, strength reducing defects, density, moisture content, growth rate and grain slope.³ Hundreds of destructive tests of machine graded, full sized pieces of dimension proved remarkable consistency between "E" and "f" values.⁴ Table I presents this correlation and other corresponding strength properties as determined by the Western Wood Products Association. Table II presents those as determined by the Southern Pine Association.

¹"The Modern Concept . . .," p. 3.

²Ibid.

³"Simpson EMSR Structural Lumber . . .," p. 502.

⁴Ibid.

TABLE I
ALLOWABLE STRESSED FOR MACHINE STRESS RATED LUMBER¹
(Applies to lumber 2" or less in thickness)

(Any moisture content)			"C _L " Compression (Dry)				**Horizontal Shear "H" (Dry)			
Extreme fiber in bending	Modulus of Elasticity	Tension and Compression Parallel to Grain	D.Fir- Larch	West.Hemlock White Fir	Pond. Pine	Engel. Spruce	D.Fir- Larch	West. Hemlock	Pond. Pine	White Fir Engel. Spruce
"f"*	"E"	"t" & "C _L "								
900	1,000,000	725	390	365	310	215	--	--	--	--
1200	1,200,000	950	390	365	310	215	95	80	90	75
1500	1,400,000	1200	390	365	310	215	110	90	100	80
1800	1,600,000	1450	390	365	310	215	120	100	110	90
2100	1,800,000	1700	415	365	310	215	135	115	125	105
2400	2,000,000	1925	455	365	310	215	135	115	125	105
2700	2,200,000	2150	455	365	310	215	135	115	125	105
3000	2,400,000	2400	455	365	310	215	135	115	125	105
3300	2,600,000	2650	455	365	310	215	135	115	125	105

*The above stresses are for lumber used on edge. When loaded flatwise, "f" may be increased 18%.

**Horizontal shear values apply to 1800f-1.6E and higher classifications when the length of through checks and splits does not exceed $\frac{1}{2}$ the width of the piece. The above values apply to 1500f-1.4E and lower classifications when the length of through checks and splits does not exceed the width of the piece.

¹1965 Standard Grading Rules (Portland, Oregon: Western Wood Products Association, 1965), p. 225.

TABLE II
ALLOWABLE STRESSES FOR MECHANICALLY STRESS-RATED LUMBER
SOUTHERN PINE ASSOCIATION¹

Modulus of Elasticity "E"	Extreme fiber in bending "f"	"t" and "c" Tension and Compression Parallel to Grain	Horizontal shear "H"	Compression perpendicular to grain "c _⊥ "
1,000,000	1050	850	90	390
1,200,000	1350	1050	100	390
1,400,000	1650	1300	115	390
1,600,000	1900	1500	125	390
1,800,000	2200	1750	140	390
2,000,000	2500	2000	150	455
2,200,000	2800	2250	165	455
2,400,000	3100	2450	165	455
2,600,000	3400	2700	165	455
2,800,000	3700	2950	165	455
3,000,000	4000	3200	165	455

¹Robert J. Hoyle, Jr., "Electro-Mechanical Stress Grading of Two-inch Structural Lumber" (Presented at the 1963 Annual Meeting of the American Society of Agricultural Engineers; Lewiston, Idaho: Potlatch Forests, Inc., 1963), p. 2.

APPENDIX B

CLT-1

The CLT-1 is produced by Industrial Sciences, 712 S. E. Hawthorne Blvd., Portland 14, Oregon.

Specifications

Machine size: 17' 0" long x 36" wide x 48" high.

Weight: Approximately 11,000 lbs.

Power requirements: 440 volts, 3-phase, AC - 120 volts, 200 watts, A.C.

Material sizes: Dimension - 8' to 26' long - 12" maximum width.

Production capacity: Speeds to 1000 lineal fpm.

Mechanical features: Heavy steel castings; single dial setting for changing board width; air cushioned fences; compact stamper; mechanical counters tally day's production by grade, total, rejects.¹

Cost: Approximately \$45,000.²

Operational Sequence³ (See Figure 1).

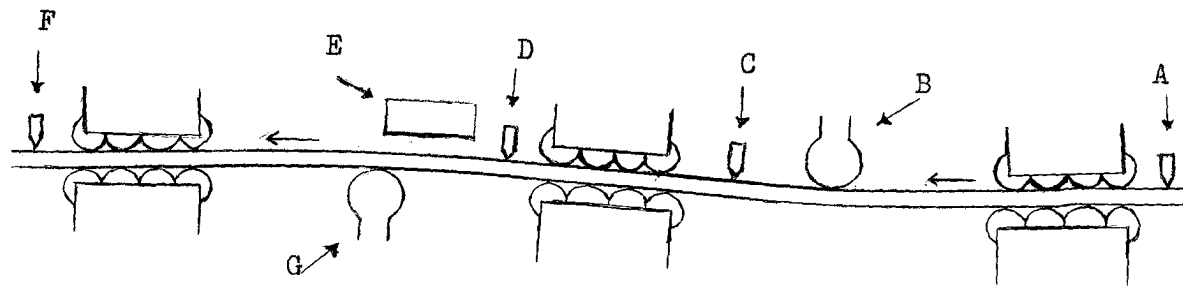
1. Traveling board interrupts light source for photo-electric Sensor No. 1, alerting first section of the electronic system.

2. Powered clamp-up roll section feeds board into the machine and firmly holds the board, preventing tail whip or vibration past

¹"The Modern Concept . . .," p. 8.

²"Two Stress Grading Machines . . .," p. 86.

³"The Modern Concept . . .," p. 7.



- A - Sensor No. 1
- B - Transducer No. 1
- C - Sensor No. 2
- D - Sensor No. 3
- E - Grade Stampers
- F - Sensor No. 4
- G - Transducer No. 2

FIGURE 1. DIAGRAM OF CLT-1 STRESS RATING PROCESS

this point.

3. Board passes Sensor No. 2, alerting second section.
4. Board enters second powered roll section and is induced to deflect.
5. Board passes Sensor No. 3, arming first section and activating Transducer No. 1.
6. Transducer No. 1 reports readings at 6-inch intervals and total readings are stored.
7. Final powered roll section induces opposite deflection.
8. Board passes Sensor No. 4, arming second section and activating Transducer No. 2.
9. Transducer No. 2. reports readings at 6-inch intervals and total readings are stored.
10. Tail of board passes Sensor No. 1, restoring light source and deactivating Transducer No. 1.
11. Tail of board passes Sensor No. 2, initiating computation of stored information from Transducers No. 1 and No. 2, activation of the proper grade stamp, and reset of the electronic system for the next sequence.

APPENDIX C

STRESS-O-MATIC

The Stress-O-Matic is produced by Tri-State Machinery Company,
2231 Valdina St., P. O. Box 10772, Dallas 7, Texas.

Specifications¹

Machine size: 7' 4" long x 29" wide x 53" high.

Drive: 10 HP, 1800 rpm, U. S. motor.

Electrical control system: Operates on 24 volts D.C.

Material sizes: Dimension - 8' with no limit to maximum length
- 12" maximum width.

Production capacity: Speeds to 600 lineal fpm.

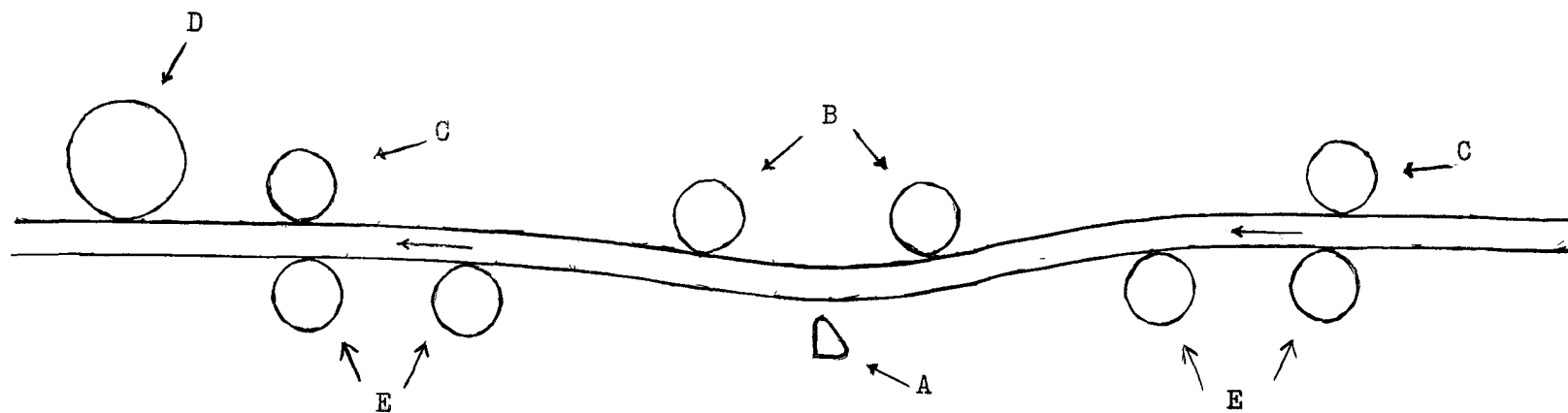
Mechanical features: Heavy cast iron base frame; heavy duty
top quality ball or roller bearings; 4-3/8" diameter tubing (hard
chrome plated) rolls with 2" diameter shafts turning in ball bearings;
exclusive feature allows pieces to be fed butted up so that net output
is equivalent to input feed speed.

Cost: Approximately \$13,050.

Operational sequence (See Figure 2).

1. Piece enters machine from level slightly below top of first
bottom fixed roller lifting the first top infeed switch roll, activating
a new test cycle and the time delay relay to load the piece just

¹"Model 3572 Stress-O-Matic . . .," pp. 1-3.



- A - Deflection Actuator
- B - Center Load Rolls
- C - Infeed and Outfeed End Reverse Load Rolls
- D - Grade Stamp
- E - Support Rolls

74

FIGURE 2. DIAGRAM OF STRESS-O-MATIC STRESS RATING PROCESS

as it bridges the test span.¹

2. Time delay relay applies all five loads at once to center load rolls as piece bridges the 48" test span and outfeed load roll for reverse bending. (Both outfeed and infeed end reverse load rolls apply as center load rolls apply.)²

3. If the piece deflects under full load the distance (pre-determined for groups of species)³ needed to reach the deflection actuator, loads are released in rapid succession until the piece holds the load without touching the deflection actuator. If the piece does not deflect to the actuator, full load is held throughout the length of the piece.⁴

4. Tail end of the piece allows the top switch roller on the infeed end to drop, releasing all loads and ending the test cycle.⁵

5. The load held by the piece without touching the deflection actuator activates corresponding stamp block in the stamp roll as the piece leaves the machine. If piece fails to pass the minimum (1200f) test, machine stripes with green ink at the first point of weakness to signify rejection.⁶

¹Pelster, "Machine Stress Rating . . .," p. 2.

²"Industrial Stress-O-Matic . . .," p. 4.

³Pelster, "Machine Stress Rating . . .," p. 3.

⁴"Industrial Stress-O-Matic . . .," p. 4.

⁵Ibid.

⁶Ibid.

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